# CHAPTER 3

## MECHANICAL UNITS

All units used in this book will be from the SI systems of units. The advantage of this system is that all quantities can be related to a base set of units. Once the student grasps the physical meaning of these few base units, he will be able to build on them in a mathematical sense, to solve problems applicable to this course.

### 3.1 DECIMAL MULTIPLES AND SUB-MULTIPLES

The abbreviated form of writing very large or small numbers involves reducing them to powers of ten. Numbers which contain many zeros may be written as positive or negative powers of ten. Typical examples of this are shown below -

| Number | Positive Powers of Ten |
|---|---|
| 10.0 | $10^1$ |
| 100.0 | $10^2$ |
| 1000.0 | $10^3$ |
| 10000.0 | $10^4$ |

It can be seen that the power of ten is the number of zeros to the left of the decimal place in the original number.

| Number | Negative Powers of Ten |
|---|---|
| $\frac{1}{10}$ | $10^{-1}$ |
| $\frac{1}{100}$ | $10^{-2}$ |
| $\frac{1}{1000}$ | $10^{-3}$ |
| $\frac{1}{10000}$ | $10^{-4}$ |

From this table it can be seen that if the number is a quotient it is written exactly the same as before but with a negative sign before the power.

Measurements of larger and smaller magnitude than the base SI units are frequently made. If only base units were available, the writing of these numbers would occupy much time and space. To avoid this, the SI system makes provision for reducing the size of numbers containing many numerals by the use of prefixes, which are merely names used as substitutes for powers of ten. Prefixes used in electricity are as shown in Table 1.

TABLE 1

| POWER OF TEN | PREFIX | SYMBOL |
|---|---|---|
| $10^{12}$ | tera | T |
| $10^9$ | giga | G |
| $10^6$ | mega | M |
| $10^3$ | kilo | k |
| $10^{-3}$ | milli | m |

| | | |
|---|---|---|
| $10^{-6}$ | micro | $\mu$ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |

It will be noticed that only powers in multiples of three are used. The prefix 'kilo' is pronounced 'kill' - 'o'.

## 3.2 SI UNITS

The base SI units used in this course are shown in Table 2.

TABLE 2

| PHYSICAL QUANTITY | NAME | SYMBOL |
|---|---|---|
| length | metre | m |
| mass | kilogram | kg |
| time | second | s |
| electric current | ampere | A |
| luminous intensity | candela | cd |

Use will now be made of the base units of mass, length and time, to derive expressions involving coherent units, which are expressions in which any two unit quantities in the system form the unit of the resultant quantity.

### (a) CONSTANT VELOCITY

Velocity is the time rate of change of motion. It is the uniform rate at which a distance between two points is traversed. The unit for velocity is -

$$\frac{\text{distance}}{\text{time}} = \frac{m}{s} = ms^{-1} \quad \text{(metres per second)}$$

If the time taken for a body to move through a given distance is known, its velocity may be calculated.

Example 3.1

A car travelling in a straight line takes 8 minutes 20 seconds to cover a distance of 5 kilometres. Calculate its velocity.

$$l = 5 \times 1000 = 5000 \text{ m}$$

$$t = (8 \times 60) + 20 = 500 \text{ s}$$

$$v = \frac{\text{distance}}{\text{time}} = \frac{5000}{500} = 10 \text{ ms}^{-1}$$

Converting to the more commonly used unit, the kilometre per hour, gives -

$$v = \frac{10 \times \text{(second per hour)}}{\text{(metres per kilometre)}} = \frac{10 \times 60 \times 60}{1000} = 36 \text{ kilometres per hour.}$$

**(b) UNIFORM ACCELERATION**

Acceleration is the time rate of change of velocity. A car starting from rest has to accelerate to reach a constant velocity, or a car changing from one velocity to another has to accelerate in a positive or negative sense, depending upon whether its velocity is increasing or decreasing respectively. The unit for acceleration is obtained from -

$$\frac{\text{velocity}}{\text{time}} = \frac{ms^{-1}}{s} = ms^{-2}$$ (metres per second squared)

If the time taken to change from one velocity to another is known, the acceleration of a body may be calculated.

**Example 3.2**

A car at rest is uniformly accelerated for 5 seconds, after which time it has reached a velocity of 36 kilometres per hour. Determine its acceleration -

$$v = \frac{36 \times 1000}{60 \times 60} = 10\ ms^{-1}$$

$$t = 5\ s$$

$$a = \frac{\text{velocity}}{\text{time}}$$

$$= \frac{10}{5}$$

$$= 2\ ms^{-2}$$

**(c) FORCE**

When a body of a certain mass is being accelerated a force will be exerted on that body, the magnitude of the force depending upon how great the acceleration. People are aware that if they are in a vehicle which is rapidly accelerated they will be thrust backward, whereas if the vehicle is accelerated slowly, they do not experience the same force. A heavy person will experience a greater thrusting motion than a lighter person for the same amount of acceleration. The unit for force is given by the product of acceleratior and mass = ma = kg $ms^{-2}$ (kilograms metre per second squared). The name given to the unit of force is the newton (N).

**Example 3.3**

A vehicle with a mass of 1000 kg is accelerated uniformly at 5 metres per second squared. Calculate the force exerted on the mass of the car.

mass = 1000 kg

acceleration = 5 $ms^{-2}$

$$F = ma$$

$$= 1000 \times 5$$

$$= 5000\ kg\ ms^{-2}$$

$$= 5000 \text{ newtons}$$

$$= 5000\ N$$

**(d) WORK**

If a force is exerted on a body and it moves through a distance, work is said to be done on that body. The movement may be in any direction. If the movement is in the horizontal plane the unit for work is given by force times distance = kg $ms^{-2}$ x m = kg $m^2\ s^{-2}$ (kilogram metres squared per second squared). If the work is done vertically against the pull of gravity (g = 9.81 $ms^{-2}$) then the unit for work is given by W = m g h = kg x $ms^{-2}$ x m = kg $m^2\ s^{-2}$, which is the same as for horizontal work. The name given to the unit of work is the joule (J).

$$w = m\,g\,h$$

**Example 3.4**

A car having a mass of 1000 kg, is lifted 10 m from a wharf to the deck of a ship. Calculate the work done on the car.

mass = 1000 kg

g = 9.8 $ms^{-2}$

h = 10 m

$$w = m\,g\,h$$

$$= 1000 \times 9.8 \times 10$$

$$98000\ kg\ m^2\ s^{-2}$$

$$= 98000 \text{ joules}$$

$$= 98\ kJ$$

## (e) POWER

Power is the rate of doing work. The work done on a given mass is the same regardless of the time taken to do this work. The power required to do this work, however, depends on the time taken. The shorter the time required to complete the work, the greater the power necessary. The unit for power is -

$$\frac{\text{work}}{\text{time}} = \frac{\text{kg m}^2\ \text{s}^{-2}}{\text{s}} = \text{kg m}^2\ \text{s}^{-3}$$ (kilogram metre squared per metre cubed).

The name given to the unit of power is the watt (W).

### Example 3.5

A load of 10,000 bricks, each having a mass of 3.5 kilograms, is raised 30 metres to the top of a block of home units. If the total lifting time taken is 20 minutes, calculate the power required by the hoist motor.

mass $= 10{,}000 \times 3.5 = 35000$ kg

g $= 9.8\ \text{ms}^{-2}$

h $= 30$ m

t $= 20 \times 60 = 1200$ s

$$P = \frac{W}{t} = \frac{35000 \times 9.8 \times 30}{1200} = 8575\ \text{kg m}^2\ \text{s}^{-3}$$

$= 8575$ watts

$= 8.575$ kW

### SUMMARY OF SI COHERENT UNITS

| PHYSICAL QUANTITY | UNIT | NAME | SYMBOL |
|---|---|---|---|
| Velocity | $\text{ms}^{-1}$ | | |
| Acceleration | $\text{ms}^{-2}$ | | |
| Force | $\text{kg ms}^{-2}$ | newton | N |
| Work | $\text{kg m}^2\ \text{s}^{-2}$ | joule | J |
| Power | $\text{kg m}^2\ \text{s}^{-3}$ | watt | W |

Equations in chapter

(1) $v = \frac{\text{distance}}{\text{time}}$

(2) $a = \frac{v}{t}$

(3) $F = ma$

(4) $W = mgh$

(5) $W = F \times \text{distance}$

(6) $P = \frac{W}{t}$

## TUTORIALS 1.3

(a) Indices Conversions

(1) 3690J to kJ

(2) 8460mm to m

(3) 0.068 km to m

(4) 28 $\mu$s to s

(5) 63 kg to g

(6) 0.016 kJ to J

(7) 11.2 kW to W

(8) 92 m to km

(9) 524W to kW

(10) 386431 mm to km

(b) Mechanical problems

Tutorials

(i) Determine the time taken for a vehicle travelling at a uniform velocity of 60 kilometres per hour to move a distance of 700 metres.

(ii) Calculate the force on a body of 10,000 gms. when it is undergoing an acceleration of 4 metres per second per second.

(iii) A load of 5,000 concrete blocks, each having a mass of 500 gms. is raised 36 metres to the top of a block of home units. Calculate the work done on the bricks.

(iv) Fifty kilowatts of power are required to raise a certain load by 100 metres in 2 minutes. Calculate the mass of the load.

(v) Determine the power required to raise 100 bags of cement, each having a mass of 45 kg, from ground level to a height of 100 m above ground if the lift takes 2 minutes.